Table 5.4-3
Uplink Capacity Estimates
PFD=-140 dBW/4KHz/m2

System	No. Systems	CDMA Parameter Set	Weak Fading/Modified Parameter Set	
			Infinite Range	Finite Range
ARIES	1	1349	955	0
	2	896	634	0
	3	671	475	0
	4	536	380	0
	5	446	316	0
ELLIPSO	1	2173	1413	0
	2	1443	938	0
	3	1080	702	0
	4	863	561	0
	5	719	467	0
GLOBAL	1	3696	2678	2678
	2	2455	1778	1278
	3	1838	1331	0
	4	1469	1064	0
	5	1048	886	0
ODYSSEY	1	3856	2395	0
	2	2561	1590	0
	3	1917	1191	0
	4	1532	951	0
	5	1276	792	0
CELSTAR	1	19976	8426	8426
	2	13267	5596	5596
	3	9931	4189	4189
	4	7936	3347	1343
	5	6608	2787	0

dynamic range limitations. The last column shows that ARIES, ELLIPSO and ODYSSEY cannot close the link at the required maximum fade margin. The finite dynamic range results and a comparison with the IRIDIUM CONUS capacity are shown in Figure 5.4.2-1.

Because three systems cannot close their link for service to shadowed users, it would appear that a lower PFD would provide a better operating point. The value of -143 dBW/4KHz/m^2 was also evaluated by the CDMA applicants. In the remainder of this section, capacity will be evaluated using PFD values of -143 and -146.

The capacity analyses for all three PFD values are summarized in Annex 5.2, Tables 2.1-2.3. In the bottom part of these tables there are two rows corresponding to the calculation with and without dynamic range effects. The capacity for the ARIES system is zero for the fade model criteria selected even at the lowest PFD value of -146. For the other four systems the capacity is the minimum of the two rows if there is a number in each row. The absence of a number for these systems means that the infinite dynamic range result applies. The capacity results for the PFD=-143 are plotted in Figure 5.4.2-2. The sudden drops in capacity for the systems when an additional system is introduced is caused by insufficient dynamic range to accomodate both the increased interference and the fade model criterion. At the lower PFD value there is more dynamic range sometimes resulting in larger capacity for systems with handsets in the dynamic range limited region as shown in Fig. 5.4.2-3. The dynamic range limited cases are indicated in these figures by solid lines and the unlimited capacity results are given by the dashed lines. The latter case corresponds to system applications which do not serve portable handsets. The former case corresponds to systems which have a requirement to serve some fraction of the users with handsets.

For vehicular service only, the larger PFD of -140 provides good capacity values with interference sharing. When handset user service is anticipated, lower PFD's are desirable in order to increase the potential for sharing.

The effect of interference sharing on the maximum average fade margin for the five systems can be seen in Figure 5.4.2-4. This figure shows a general result that interference sharing causes a reduction in maximum average fade margin as the number of systems increases. Thus CDMA operators must initially design their systems for more maximum average fade margin than needed. If more systems are in place than anticipated, service objectives will have to be compromised if capacity objectives are to be maintained.

This figure also demonstrates the necessity for diversity. Referring to Table 5.4.2-1, the maximum average fade margin for a no diversity system is estimated at 9 + 7 = 16 dB. Obtaining this level of fade margin under the interference sharing rule is not practically possible.

Figure 5.4.2-1 Uplink CDMA Capacity (8.25 MHz)

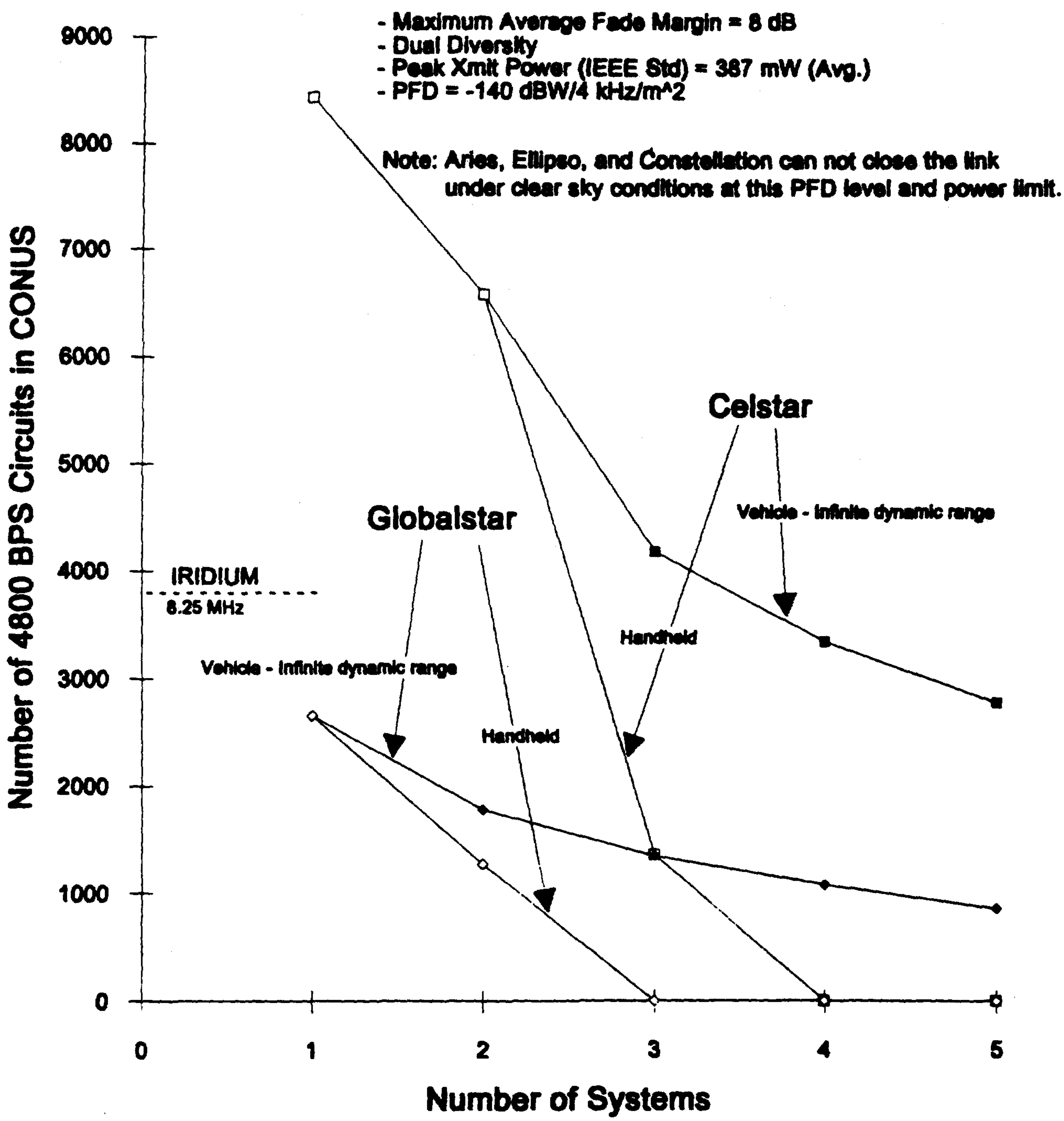


Figure 5.4.2-2 Uplink CDMA Capacity (8.25 MHz)

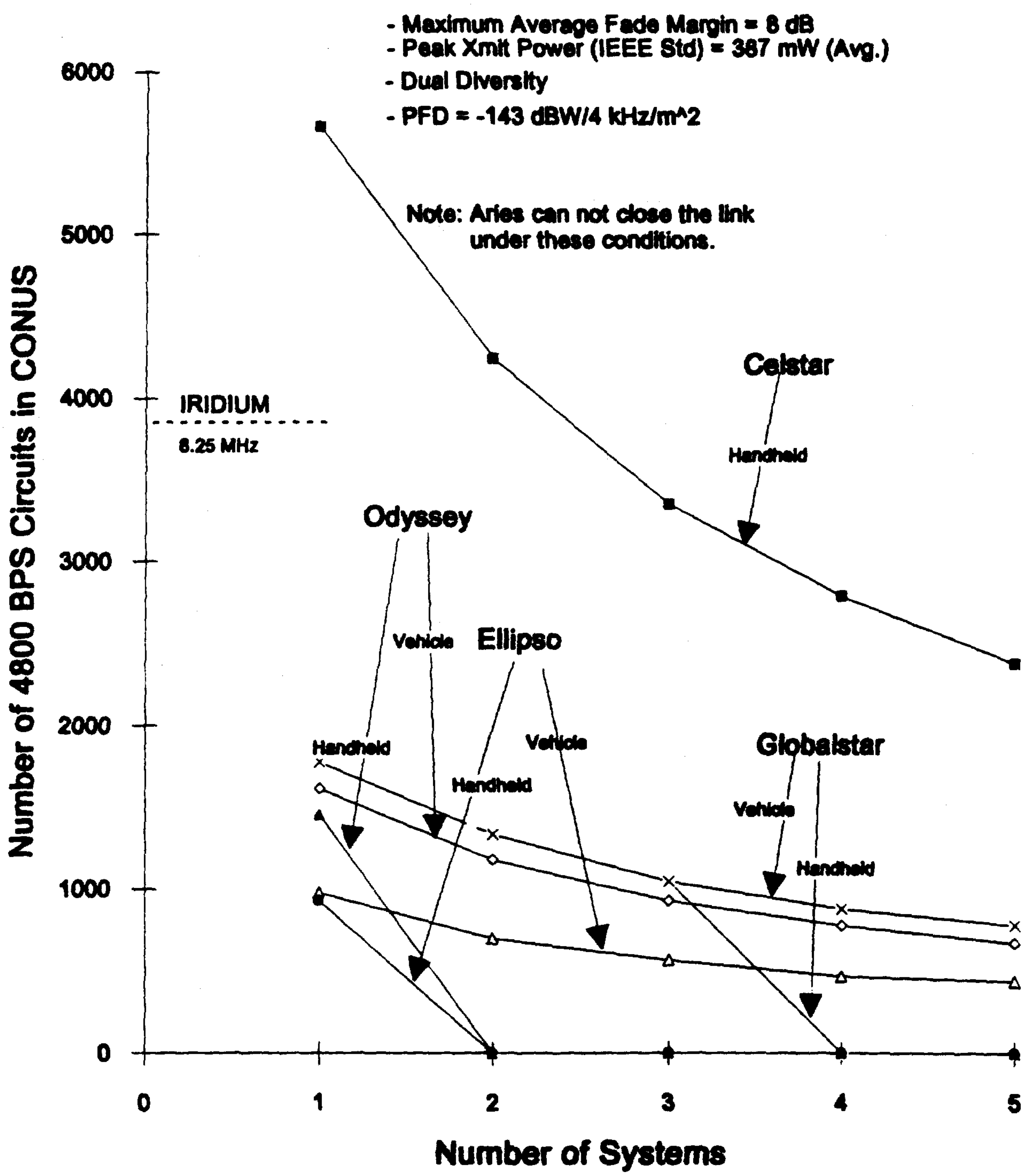


Figure 5.4.2-3 Uplink CDMA Capacity (8.25 MHz)

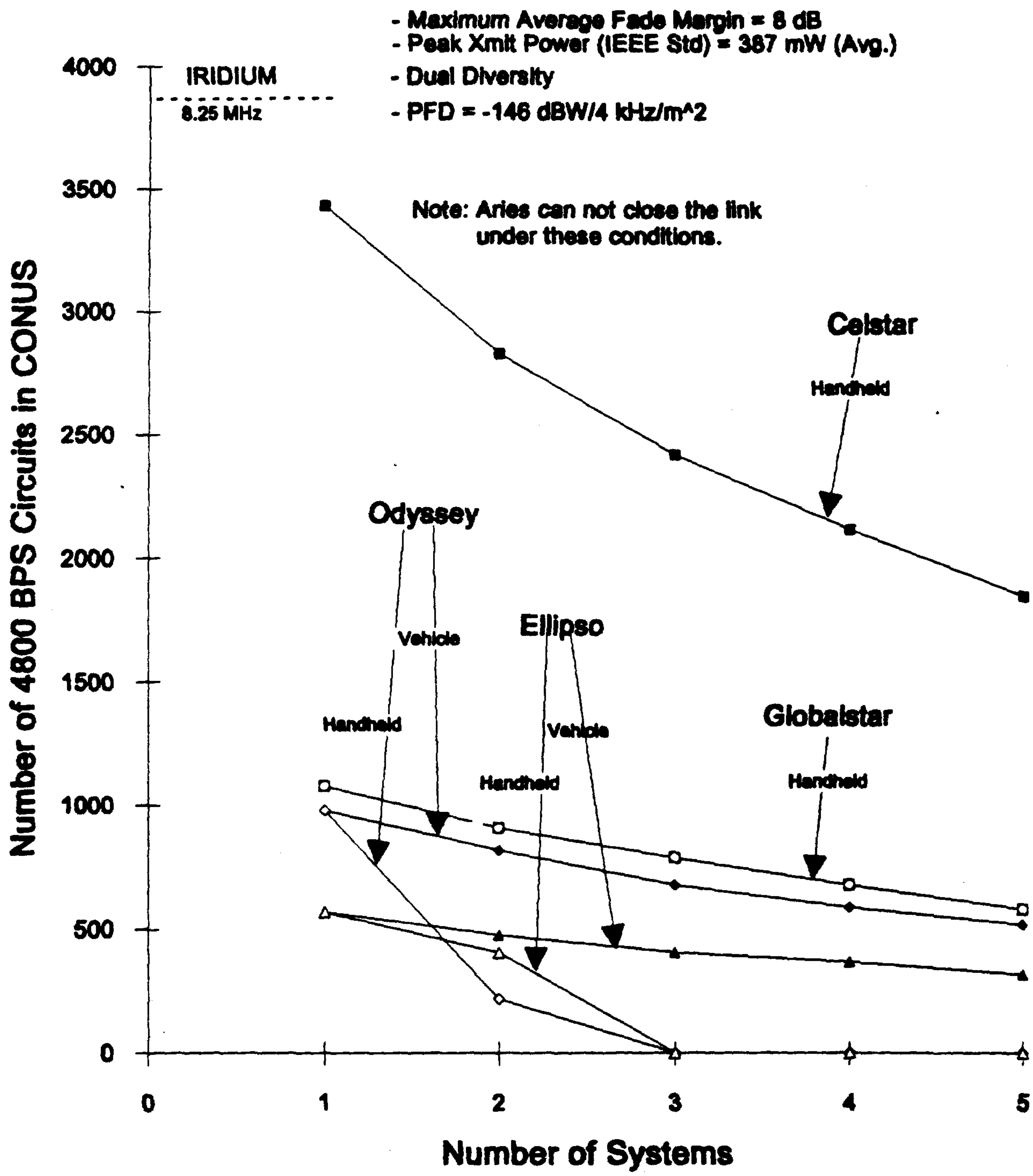
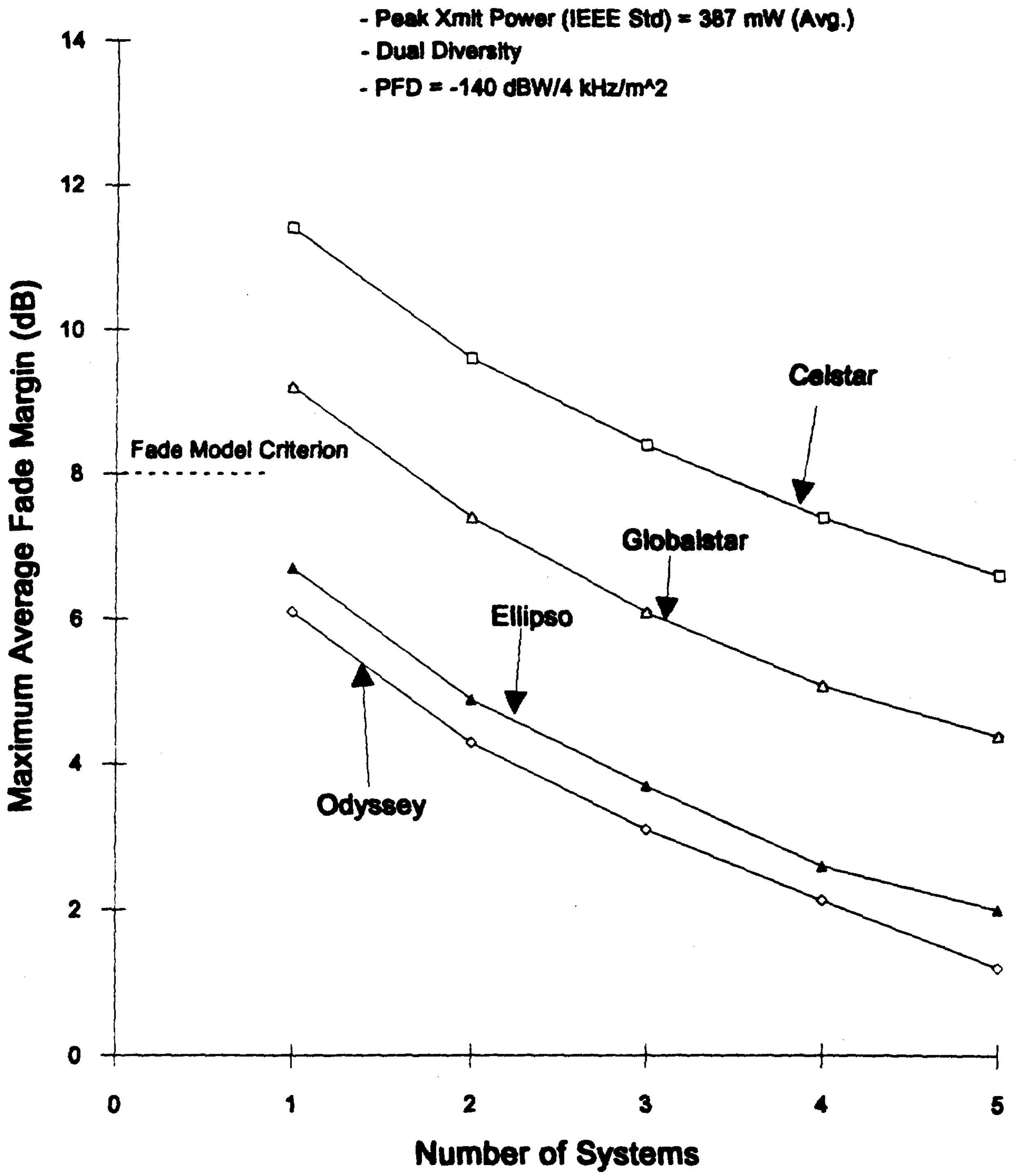


Figure 5.4.2-4 Sharing Effects on Fade Margin



5.4.2.3.3 Summary

The analysis and results presented in this uplink analysis section lead to the following conclusions:

1) Systems that cannot close their link for a fixed fade criterion will have to lower their service quality (higher drop call rate) in order to continue operation as more systems are introduced.

2) Even with dual diversity operation, dynamic range limitations were significant in all of the 5 proposed systems. Even at the lowest PFD of -146, only 2 of the 5 systems can share.

3) Operation at lower PFD values in order to meet fade objectives results in lower capacity.

4) Fade margins go down as the number of shared systems increases. System design must initially provide more margin than required if service objectives are to be maintained as additional systems are added.

5) Dual diversity is required for shadow-resistant systems under the interference sharing rule. This is a complexity factor as it requires almost twice as many satellites for world-wide coverage.

5.4.3 Realizable Downlink Capacities

5.4.3.1 System Data Required for Analysis

The following downlink system parameters are required to perform the analysis. Each parameter is briefly defined and described.

(A_d) Baseband Bit-Rate

This is the total downlink baseband bit-rate required for a single voice channel. It should include all signalling overhead.

(B_d) Channel Activity Factor

This parameter (which should be between zero and one) should be included if the system intends to exploit voice activity by reducing the transmit power in the downlink during the natural pauses in speech. This parameter is the numerical ratio of the average power to the peak power accounting for only the power reductions attributed to pauses in speech. Alternatively, if some form of Digital Speech Interpolation (DSI) is implemented, which produces a corresponding channel efficiency gain, this should be included here as the inverse of the average number of virtual channels multiplexed in an individual signal.

(C_d) Total RF Bandwidth

This is the total occupied downlink RF bandwidth used by the system.

(D_d) Minimum Operating Eb/No

This downlink parameter, which is a function of the modulation scheme and modern implementation, is normally represented in dB form, but needs to be converted to a linear power ratio to substitute in the capacity equation.

(E_d) Number of Satellite Beams to Provide CONUS Coverage

This is the total number of downlink beams, irrespective of the number of satellites, used to implement CONUS coverage. If there are separate satellites in the same system providing co-coverage, the beams in the areas of overlap should only be counted once.

(F_d) Beam Frequency Re-Use Factor

This parameter is a measure of the degree to which the downlink frequency band is re-used spatially among the beams. The value of this parameter is "N", where frequencies are re-used once in every "N" beams. For example, a system with re-use in every beam has a value of N=1. A system with full frequency re-use in every third beam has a value of N=3.

(G_d) Average Propagation Margin

This is the downlink power margin required, in dB, at any instant in time, averaged over all the users in the CONUS coverage of the system, used to overcome propagation impairments relative to free space.

(H_d) Average Orbit and Beam Effects

This parameter takes account of the combined effect of downlink range differences and downlink antenna gain contour effects. It is essentially a dB value that is equivalent to the average extra satellite power required to communicate with all the users distributed throughout the area covered by an individual downlink beam, compared to the situation if all those users were located at the optimum location in the area covered by an individual downlink beam, where G/R^2 is at a maximum (G = satellite antenna gain; R = range to the satellite). It accounts for the difficulty of building a perfect satellite antenna.

(J_d) Average Power Control Implementation Margin

This is a dB value which is a result of imperfect downlink power control. It is equal to the average amount by which the link power exceeds the minimum necessary to sustain the link, if power control were perfect.

(K_d) Average Beam Overlap Factor

This takes account of the spillover between downlink beams. It is the ratio, in dB, averaged over all the users throughout the CONUS coverage, of the power from the intended plus adjacent beams to the power from the intended beam only. Its value is highly dependent on the Beam Frequency Re-Use Factor (see item (F_d) above).

(L) Effective Aperture of the Mobile Receive Antenna(A_e)

The minimum effective aperture of the mobile receive antenna under operational conditions, calculated from the corresponding gain at the frequency of 2,500 MHz.

(M) System Noise Temperature of the Mobile Receiver (T_m)

The maximum system noise temperature of the mobile receiver under operational conditions.

5.4.3.2 Downlink Analysis Method

The downlink capacity for each system can be derived by first determining the maximum realizable downlink capacity (C_{MRD}) for each system as a function of PFD spectral density using the following formula:

$$C_{MRD} = (C_d \cdot E_d)/(A_d \cdot B_d \cdot D_d \cdot F_d)/(10\wedge(\Delta_D/10))$$

$$\text{where } \Delta_D = G_d + H_d + J_d + K_d \quad \text{(in dB)}$$

This capacity figure, however, will never be attained for practical systems due to weight and power limitations of the satellites in orbit. Therefore, the next stage in the analysis is to derive downlink capacity numbers for each system assuming realistic operating downlink Power Flux Density (PFD) spectral density (p_{sd}) values.

These individual system capacities must be adjusted further to reflect the interference sharing environment in which all of the proposed systems would operate in by varying the amounts of interfering co-polar PFD (p_{id}) due to other sharing systems. First it is necessary to calculate the effective downlink thermal noise equivalent flux density in a 4 KHz bandwidth (p_{nd}) for each system, which is given by the following equation:

$$p_{nd} = (k \cdot T_m \cdot 4000)/A_e$$

where: k = Boltzmann's constant ($= -228.6 \frac{\text{dBW}}{\text{Hz}\cdot\text{K}}$)

T_m = Mobile receive system noise temperature (typically = 290K or 24.6 dBK)

A_e = Effective aperture of mobile receive antenna (= -29 dBm^2 for an omni-directional antenna at 2,500 MHz)

For the case of an omnidirectional antenna, this equation gives a value for p_{nd} of -139.0 $dBW/m^2/4KHz$. This is the equivalent PFD at the mobile receive antenna that would be required to produce the mobile receive system noise temperature corresponding to T_m.

The realizable downlink capacity (C_{RD}) of the system, when operating without other interfering systems present, can now be related to the maximum realizable downlink capacity (C_{MRD}),the maximum operating PFD (p_{sd}), and the effective thermal noise equivalent flux density in a 4 KHz bandwidth (p_{nd}) by the following equation:

$$C_{RD} = (C_{MRD} \cdot p_{sd}) / (p_{sd} + p_{nd})$$

The impact of interfering co-polar power flux density from other co-frequency systems (p_{id}) and dual satellite diversity can also be taken into account using the following equation:

$$C_{RD} = (C_{MRD} \cdot p_{sd}) / (\beta p_{sd} + p_{nd} + p_{id})$$

where β = 0 with no satellite diversity
= 0.5 with dual satellite diversity

All non-GSO CDMA systems were assumed to use dual satellite diversity.

5.4.3.3 Results of Downlink Analysis

The following table shows the parameters for each system, the values chosen for the degraders and enhancers, and the calculated CONUS capacities derived from the above formulas assuming an available RF downlink bandwidth of 8.25 MHz, and p_{sd} values of between -139 $dBW/m^2/4KHz$ and -142 $dBW/m^2/4KHz$ for each of the systems.

System Parameter	Units	AMSC	Constell'n	Ellipsat	Globalstar	Odyssey	Celsat
Baseband Bit-Rate	(kBPS)	3.0	4.8	4.8	4.8	4.8	5.0
Channel Activity Factor	(#)	0.50	0.50	0.50	0.50	0.50	0.50
Total RF Bandwidth	(MHz)	8.25	8.25	8.25	7.50	8.25	8.25
Minimum Operating Eb/No	(dB)	4.0	3.0	3.0	3.5	3.5	4.0
Number of Beams in CONUS	(#)	6	10	10	20	16	149
Beam Frequency Re-Use Factor	(#)	1	1	1	1	1	1
Average Propagation Margin	(dB)	2.50	2.50	2.50	2.50	2.50	2.50
Average Orbit & Beam Effects	(dB)	2.50	3.50	2.50	2.11	2.00	1.70
Average Power Control Impl. Mar.	(dB)	1.50	2.00	1.00	1.00	1.00	2.00
Average Beam Overlap Factor	(dB)	1.00	1.00	1.00	1.04	1.25	3.80
Effective Aperture of Mobile Ant.	(dBm2)	-21.0	-29.0	-29.0	-29.0	-29.0	-29.0
Channel Overhead - pilot	%	23.4	23.4	23.4	23.4	23.4	23.4
Noise Temp. Mobile System	(K)	325	290	290	290	290	290
Maximum Realizable Downlink Capacity Limit @ -142	(# of ccts)	2047	663	1051	1845	1587	5963
Maximum Realizable Downlink Capacity Limit @ -139	(# of ccts)	2583	1104	1749	3072	2642	9966

23.4% Channel overhead is from LQSS design (IWG1-11) and applied equally to all systems.

The values chosen for several of the parameters listed above are primarily based upon the data provided by the CDMA applicants and Celsat to Drafting Group A of Informal Working Group 1. There was some disagreement in that drafting group as to the correct values to insert for the channel activity factor and propagation margins. In addition, it appears that none of the CDMA proponents took into consideration the overhead allowance required for their systems. Motorola is of the view that the CDMA proponents have seriously underestimated the effects of several of these capacity degraders and have overestimated certain claimed capacity enhancers, such as the effects of polarization isolation.

Propagation Effects

This analysis assumes slightly higher propagation margins for both the uplink and downlink cases. In particular, a margin of 2.5 dB for the downlink was assumed. None of the CDMA applicants presented any evidence justifying their relatively optimistic assumptions as to propagation losses in the frequencies of interest. Motorola believes that average losses of as much as 5 dB will be experienced by the CDMA systems, or approximately 3 dB more than was assumed in the Drafting Group A report. Accordingly, the values chosen for this factor here appear to be conservative. The justification for the average propagation margin selected here is as follows:

The increase in multiple-access-interference (MAI) on the downlink due to propagation margin can be estimated from a two state shadowing model where β is the fraction of shadowed users. If the conditional fade margin for shadowing is s, the contribution to MAI due to average propagation margin is given by

$$G_d = 1-\beta-\beta s.$$

The uplink analysis used a fading model under dual diversity conditions which assumed $\beta = 0.15$ and a value of s of 8 dB. The conditional fade margin s consists of 5 dB attenuation and 3 dB modem degradation components, c.f. Table 5.4-1. The average fade margin G_d is equal to 2.5 dB for these conditions.

A CCIR Document presented by Motorola (IWG-1-8) reports on the results of propagation field tests in the L-band. Figure 2 of that document shows the effects of both head blockage for a portable handset and shadowing in the form of trees. These tests tend to support the view that the values chosen for this analysis are correct, even if complete diversity is assumed for all of the CDMA systems. Diversity alone is not sufficient to overcome the effects of shadowing and fading. Moreover, sufficient link margin must be included before any system is developed, built, and launched, because once a system is in orbit this level cannot be increased without putting the first system at a serious, if not impossible, operational disadvantage. Therefore, it is important to err on the side of having slightly more, rather than less, link margin.

Channel Activity Factor

Downlink capacities of systems will also be affected by values chosen for the channel activity factor. Although the channel activity factor should be about the same for all systems, different CDMA proponents have selected different values for this factor. A conservative value for this factor is at least .50, a number chosen by several, but not all, of the CDMA proponents.

Overhead Factor

None of the CDMA applicants included any overhead factor in their capacity calculations for such transmissions as paging, beacons, etc. In a presentation to Informal Working Group 1 (IWG1-11), LQSS indicated that the overhead factor for its system was approximately 23 percent. It was assumed that the other CDMA systems would have comparable factors for their systems. This overhead factor will reduce capacities by way of a reduction in available RF power for the traffic channels.

Polarization Effects

When a signal is reflected off a nearby object, or when the signal passes through any amount of foliage, or when it passes through any other form of ground clutter, the polarization is distorted. MSS system users will be located everywhere, and accordingly, systems cannot rely on polarization to protect them from interference from other systems (i.e., to improve intersystem performance) or to enhance intrasystem performance. Thus if polarization discrimination is used between systems, when a user suffers a fade, his interference will also go up as he loses the discrimination protection. For this reason, the CDMA analysis uses 0 dB for a cross-polarization value.

Collective CONUS system capacities in 8.25 MHz of downlink spectrum are shown in the following table. These figures assume that

Scenario - Downlink	AMSC	Constell'n	Ellipsat	Globalstar	Odyssey	Celsat	Total
Case A: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-142.0	-142.0	-142.0	
Resulting Capacity (# ccts)	327	221	351	616	530	2140	**4186**
Case B: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-142.0	-142.0		
Resulting Capacity (# ccts)	402	255	405	711	611	0	**2385**
Case C: Max. PFD (dBW/m2/4kHz)		-142.0	-142.0	-142.0	-142.0		
Resulting Capacity (# ccts)	0	302	478	840	722	0	**2342**
Case D: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0	-139.0	-139.0	
Resulting Capacity (# ccts)	338	255	405	711	611	2497	**4818**
Case E: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0	-139.0		
Resulting Capacity (# ccts)	419	302	478	840	722	0	**2762**
Case F: Max. PFD (dBW/m2/4kHz)		-139.0	-139.0	-139.0	-139.0		
Resulting Capacity (# ccts)	0	369	584	1027	883	0	**2862**

Assumes Orthogonal CDMA, no polarization isolation

all of the CDMA systems are operating co-frequency and co-coverage in an interference sharing environment. All systems are assumed to be operating using orthogonal CDMA in the downlink and with dual satellite diversity. The cases shown in this table reflects varying PFD levels used by each system and different assumptions as to which of the proposed systems are actually in operation at the same time.

5.4.3.4 Sensitivity Analysis of Downlink Results

The results calculated above are extremely sensitive to variations in the values chosen for some of the parameters in the above formulas. The effect of varying the capacity/performance degraders is generally linear, i.e., each 3 dB of additional degradation reduces CDMA capacity by a factor of 2. For example, if it is assumed that propagation losses are really 3 dB higher than is assumed in this analysis, then all of the CDMA system capacity numbers shown above need to be divided in half.

5.5 Summary of FDMA/TDMA and CDMA Capacities Under Band Segmentation Sharing Rules

5.5.1 Introduction

This section derives the realizable capacities and spectral efficiencies for multiple MSS systems, and shows how they can share with one another and with similar systems.

For the purposes of this analysis the following MSS bands and directions of transmission are assumed. The 2483.5 to 2500 MHz band is available for downlinks as a co-primary service, the 1610 to 1626.5 MHz band is available for uplinks as a co-primary service, and the 1613.8 to 1626.5 MHz band is available for downlinks on a secondary basis.

In general, systems that operate uplinks and downlinks in separate bands do so in a paired sense, meaning that the 16.5 MHz of spectrum in the upper and lower bands are assigned in conjunction with one another exactly 873.5 MHz apart. Systems that operate bi-directionally in the lower band use the same spectrum for the uplinks and downlinks. Where a bi-directional system operates in the lower band, the corresponding paired frequencies in the upper band are, therefore, available for other uses including other MSS downlinks which use the spectrum to spread their signals to better solve implementation realities. Nevertheless, it is assumed here, for the purpose of this analysis, that any unused paired spectrum in the upper band is not used for MSS.

The CDMA systems are assumed to provide diversity (a minimum of two satellites above the horizon sufficiently for each intended subscriber unit served in an area). The Iridium system provides service to the entire US and all of its territories. The other systems require diversity to operate at the capacity levels here and have made no claims beyond the CONUS, so the comparison here is limited. The Iridium system capacities for the other areas are included in Annex 5.3.

The capacities for the FDMA and TDMA/FDMA systems are as calculated in Sections 5.2 and 5.3. The capacities for the CDMA systems are as calculated in Section 5.4, and are the lesser of the downlink values and the uplink values. It is inappropriate to average the uplink and downlink capacities. The nominal power flux density allocations used for these two link types are -142 and -143 dBW/4KHz/m^2, respectively.

The areal PFD limit for the uplink can be set to any acceptable interference sharing level. For any CDMA system to successfully operate to a portable handset and to support reasonable interference-sharing capacity values, the lower value of -146 dBW/m^2/4KHz for the areal PFD gave the best sharing scenario in the uplink analysis. (See Table 2.1, Annex 5.2). If none of the CDMA systems plan to operate to a portable handset, the interference-sharing level of the PFD can be -140 dBW/m^2/4KHz to better optimize their continued capacity levels. The assumption here is that it is not acceptable to have all the CDMA systems limited in a way in which portable handsets could not be used. Therefore, the -146 dBW/m^2/4KHz level is used.

The uplink has an engineering limit associated with the dynamic range of the subscriber unit's power level. This limit affects the capacity of the proposed CDMA systems. Table 5.5.1.1 shows the interference sharing capacity limits (areal PFD = -146 dBW/m^2/4KHz) of the various systems.

Table 5.5.1.1
Uplink Capacity - All Systems Attempt to Operate to Portable Handsets

System	Polarization	Portable Handsets	Bandwidth (MHz)	1st	2nd	3rd	4th	5th
CELSTAR	(LHC)	Yes	8.25	3406	2828	2418	2111	1874
CONSTEL	(LHC)	Yes	8.25	0	0	0	0	0
ELLIPSO	(RHC)	Yes	8.25	571	416	0	0	0
GLOBAL	(RHC)	Yes	7.50	1083	899	768	671	596
ODYSSEY	(RHC)	Yes	8.25	968	213	0	0	0

If a system is operating within a business plan that plans to operate exclusively to subscribers who do not necessarily use portable handsets, the numbers in the previous table, keeping the areal PFD to -146 dBW/m^2/4KHz, are raised as shown in the following table.

Table 5.5.1.2
Uplink Capacity - Some Portable Handsets

System	Polarization	Portable Handsets	Bandwidth (MHz)	1st	2nd	3rd	4th	5th
CELSTAR	(LHC)	Yes	8.25	3406	2828	2418	2111	1874
CONSTEL	(LHC)	No	8.25	386	321	274	239	212
ELLIPSO	(RHC)	No	8.25	571	474	405	354	314
GLOBAL	(RHC)	Yes	7.50	1083	899	768	671	596
ODYSSEY	(RHC)	No	8.25	968	804	687	600	533

To reemphasize the significance of the tables above, the areal PFD needs to be -146 dBW/m^2/4KHz for the uplink for any system to operate to portable handsets with reasonable capacity levels. Secondly, if a system operates to any handsets at all, that system's capacity is limited as shown in Table 5.5.1.2. Given the capacities as shown for the current parameters of the various systems where several rows in Table 5.5.1.1 include zero values, it is assumed here that Globalstar and Celstar operate to portable handsets and the other systems have business plans that do not include portable handsets.

Table 5.5.1.3 shows the downlink capacity possible for Celstar, Constellation, Ellipsat, Globalstar and Odyssey when any combination of them operate. The actual number of CDMA channels is the lesser of the

TABLE 5.5.1.3 (Downlink Capacity)

ACHIEVABLE SYSTEM CAPACITY vs. ENTRY ORDER (@ -142 dBW/m^2/4KHz)

SYSTEM	Bandwidth (MHz)	1st	2nd	3rd	4th	5th
CELSTAR	8.25	5983	4276	3327	2723	2305
CONSTELLATION	8.25	663	474	369	302	255
ELLIPSAT	8.25	1051	751	584	478	405
GLOBALSTAR	7.50	1845	1319	1026	840	711
ODYSSEY	8.25	1587	1134	883	722	611

Table 5.5.1.4

FDMA or TDMA/FDMA Systems

		Capacity
IRIDIUM Capacity in	16.5 MHz	7748
	8.25 MHz	3854
	5.5 MHz	2556
	4.125 MHz	1907
	2.75 MHz	1258
AMSC Capacity in	16.5 MHz	1306
	8.25 MHz	653
	5.5 MHz	435
	4.125 MHz	326
	2.75 MHz	217

uplink and downlink values.

Table 5.5.1.4 summarizes the capacity levels for the FDMA and TDMA/FDMA analyses from Sections 5.2 and 5.3.

5.5.2 A Band Segmentation Sharing Scenario

A specific scenario is used here to show how the capacity of various systems would evolve using Motorola's band segmentation approach. Although a large number of alternative scenarios are possible, this one illustrates the features and resultant capacity levels available for the various types of systems. It is used for illustrative purposes only. The AMSC system used in this example is more similar to its filing than to its currently stated intentions, but a geostationary FDMA system is more illustrative and therefore used in this scenario. The other assumptions regarding this scenario are that the first system to become operational is Globalstar, followed in three month increments by the Iridium system, AMSC (as an FDMA system), Odyssey, Ellipsat, Constellation, and Celsat.

It is further assumed that Globalstar, Odyssey, Ellipsat, Constellation, and Celsat operate as channelized-CDMA or full-spread-CDMA systems that share the same spectrum using agreed-upon interference sharing criteria. The Iridium system and AMSC system employ band segmentation within their portion of the band and utilize the FDMA/TDMA dynamic sharing equation from Section 2.1 to allocate their spectrum equitably. It is further assumed that prior to AMSC becoming operational (the second of the two FDMA or TDMA/FDMA systems to do so in this scenario), it together with Iridium decides to split the sub-band 1/3 for AMSC and 2/3 for Iridium, and that for the purpose of this example, and notwithstanding the equation in Section 2.1, it remains split in that fashion.

In the calculation of capacity, the limiting case of the uplink and downlink results should be used. The uplink analysis in section 5.4.2 showed that all CDMA systems are limited by dynamic range for handset operation under the interference sharing rule. When dynamic range limits are reached, the system must either reduce capacity (sometimes to zero) or reduce service quality, e.g., fraction of shadowed users served. In the subsequent analysis the effects of dynamic range are not included because of the subjective decisions required when limits are reached. Under infinite dynamic range conditions, the downlink determines the capacity for a duplex system. Thus, the following comparison does not imply that the CDMA systems could necessarily provide the specified capacity level with handset usage.

5.5.2.1 Globalstar Becomes Operational

Globalstar, as the first system, is able to use the entire S- and L-bands since it is the only system on orbit. But, since LQSS has chosen to operate in 1.25 MHz channels in the paired band, only 16.25 MHz of spectrum (13 channels x 1.25 MHz/channel) is usable to it in each band. Operating alone in 32.5 MHz, the maximum capacity available is 2,346 channels (uplink limited), and the "channels per MHz" is (3,787/32.5 MHz) 72 channels per MHz.

5.5.2.2 Iridium Becomes Operational

Globalstar, which is already occupying virtually the entire bands, limits its operation to the lower half of each band, since a system using FDMA or TDMA/FDMA, rather than CDMA, has become operational. (Globalstar may, in anticipation of Iridium operation, have already limited itself to half the bandwidth, since in its first several months of operation it was unlikely to require such a high capacity level). Since Globalstar has chosen to operate in 1.25 MHz channels, it would only operate 6 channels and make use of 7.5 MHz of spectrum in each band. LQSS could, of course, have made a prior decision to channelize in a different fashion, and made more use of what is available to it under this scenario.

Globalstar would operate with capacities and spectral efficiencies as noted in Section 5.4. The Globalstar capacity is 1,748 channels in the CONUS, with a spectral efficiency of 108 channels per MHz.

Iridium would operate with capacities and spectral efficiencies as noted in Section 5.2. The Iridium capacity is 3,854 channels in the CONUS, with a spectral efficiency of 467 channels per MHz.

The combined capacity for both systems is 5,641 channels in the CONUS, with a combined spectral efficiency of 243 channels per MHz.

(NOTE: The Iridium system operates over the entire US and all US territories. If the added capability due to these other areas (Alaska, Hawaii, and territories) were considered, the capacity for both systems combined is 7,207 channels in the CONUS, with a spectral efficiency of 310 channels per MHz. See Annex 5.3).

5.5.2.3 AMSC Becomes Operational (in these bands)

The Globalstar capacity would remain unchanged. However, the Iridium system would have to limit its operation to two-thirds of the 8.25 MHz, according to the assumptions in Section 5.5.2, allowing 5.5 MHz for Iridium. AMSC would be able to use 2.75 MHz in the L-band and an equal amount in the S-band.

Using the formulas from Section 5.2, and only considering the CONUS and Puerto Rico, these systems would generate the following capacities:

Table 5.5.2-1

System Channels	Spectrum	Channels
Globalstar	7.5 MHz (L) 7.5 MHz (S)	1083
Iridium	5.5 MHz (L)	2556
AMSC	2.75 MHz (L) 2.75 MHz (S)	217
Total	15.75 MHz (L) 10.25 MHz (S)	3856
Spectral Efficiency (Channels per MHz)		148

5.5.2.4 Odyssey Becomes Operational

Iridium and AMSC system capacities are unaffected from what is shown in Section 5.5.1. Globalstar must interference share with Odyssey. Unlike Globalstar, however, it is assumed that Odyssey would take full advantage of the 8.5 MHz available for its use each in the L- and S-bands.

Globalstar and Odyssey would operate with capacities and spectral efficiencies as calculated in Section 5.4.

Using the formulas from Section 5.2 and only considering the CONUS, these systems generate the following capacities:

Table 5.5.2-2

System Channels	Spectrum	Channels
Globalstar	7.5 MHz (L) 7.5 MHz (S)	899
Iridium	5.5 MHz (L)	2556
AMSC	2.75 MHz (L) 2.75 MHz (S)	217
Odyssey	8.25 MHz (L) 8.25 MHz (S)	804
Total	16.5 MHz (L) 11.0 MHz (S)	4476
Spectral Efficiency (Channels per MHz)		162